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ABSTRACT

Chaos theory describes the way systems change over time. It proposes that systems governed by physical laws can undergo transitions to a highly irregular form of behavior and that although chaotic behavior appears random, it is governed by strict mathematical conditions. This paper applies chaos theory to administrative and organizational issues. Three goals are addressed. First, the use of chaos theory to model social dynamics is justified. Second, organizational theory is defined from a chaos perspective. Finally, the mathematics of chaos is applied to a simple issue of informational theory to demonstrate how new perspectives of social dynamics are gained. (34 references) (Author/RR)

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The Mathematical Modeling of Chaotic Social Structures

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Abstract

This paper applies chaos theory to administrative and organizational issues. Three goals are addressed: first, the use of chaos theory to model social dynamics is justified; second, organizational theory is defined from a chaos perspective; and finally, the mathematics of chaos is applied to a simple issue of information theory to demonstrate how new perspectives of social dynamics can be gained.

The Mathematical Modeling of Chaotic Social Structures

Recent research literature has seen numerous debates between advocates of statistical modeling, who argue in favor of the general predictability of human behavior, and advocates of the descriptive or naturalistic research, who argue that human behavior is essentially non-deterministic. The roots of these arguments have been brewing for many years in sociological and organizational theory, however. Sociologists have long argued that society, rather than being static and deterministic, is defined by multi-channeled causative interactions among sentient beings—interactions driven by communication and purposive behavior rather than physical contact (see, for example, Buckley, 1967). From this, organizational analysts have derived theories of systems interaction (Forrester, 1969, 1971; Corwin, 1987, Hoy & Miskel, 1987), contingency (Glassman, 1973; Fiedler, 1973), uncertainty (Cohen, March & Olsen, 1972), and dialectic (Benson, 1977). These organizational theories have debated issues of positivism (explanation based on regularity and causality; Hall, 1987), voluntarism (individuals are totally autonomous and free-willed; Burrell & Morgan, 1979), and structuralism versus individualism (structural stability or individual purposiveness; Pfeffer, 1982).

A potential new component of these debates, called chaos theory, has evolved over the past few years. Several have recognized its potential for describing social systems, but have failed to explore that possibility. Notable among the advocates is Lee J. Cronbach, who has suggested that "[m]etaphors and mathematical analyses flow from the study of chaos. The work will suggest analogies to almost any human scientist." (1988, p. 47) Cziko has proposed that "[d]evelopments in the field of physics [chaos] also have important implications for arguments concerning the predictability of human behavior....It thus appears only a matter of time before chaos is applied also to problems of human behavior and education." (1989, pp. 18-19)

This paper addresses three goals. First, the use of chaos theory to model social dynamics is justified; second, organizational theory is defined from a chaos perspective; and finally, the mathematics of chaos is applied to a simple issue of information theory to demonstrate how new perspectives of social dynamics can be gained.

Chaos Theory

Chaos theory describes the way systems change over time. It proposes that systems governed by physical laws can undergo "transitions to a highly irregular form of behavior...." and that although "chaotic behavior appears random, it is governed by strict mathematical conditions." (Peterson, 1988). The technical usage of the term chaos is different from its common usage in that the scientific concept implies order in the midst of disorder. Predictability and unpredictability exist together in the same set of formulas. The equations used to model change over time imply cause-effect relations, but small perturbations in the system can lead to major changes in final outcomes. Relationships that appear, initially, to exhibit linearity quickly devolve into non-linearity. Increases in variable X may create one-to-one increases in variable Y until a critical value is obtained, at which point a small further increase in X causes significant, non-linear changes in Y.

According to chaos theory, systemic state of being is sensitive to initial conditions. The phenomenon is best observed in weather forecasting, where minor fluctuations in meteorological conditions can create big changes in tomorrow's weather. This is known as the butterfly effect, which asserts, only somewhat facetiously, that the flapping of a butterfly's wings in Tokyo can cause thunderstorms over midwestern United States; (Lorenz, 1964). It is for this reason scientists have concluded that weather is ultimately unpredictable—at least in a micro sense.

In the macro sense, there is order within chaos. Chaotic structures settle into steady states much as do pendulums; both exhibit regular, or more precisely, finite behavior. Chaotic systems, however, exhibit the additional characteristic known as non-periodic behavior. In simple terms, chaotic behavior is constrained in scope yet it never quite repeats

itself. The world is not going to wake up tomorrow to snow in the morning and temperatures of 140° in the afternoon, yet nor will tomorrow's weather be a precise duplicate of today's—it will vary in at least some subtle details. Mathematically, the force that pulls a system into regular behavior is called an attractor; in chaos, the force that pulls a system into a chaotic steady state is called a strange attractor (Ruelle and Takens, 1971). The strange attractor defines the difference between a chaotic state and a random one.

Thus far, chaos theory has been limited to investigations of physical phenomena, and herein lies a dilemma for advocates of the social application of chaos theory. Sociological history is replete with examples of pitiable but popular efforts to apply physical law to social events. The social physics movement of the 17th century, for example, viewed society as a static, closed system whose component parts are in equilibrium. The organic movement of the 19th century, which evolved out of Darwin and Spencer (Social Darwinism), proposed that society mimics the harmoniously interacting subsystems of a living body. The error of such movements lies in their failure to address the interactive and purposive nature of the human condition.

The applicability of chaos to social systems must be predicated upon an explication of the differences between physical and social interaction. Two such differences are pertinent. First, human linkages are symbolic rather than tangible. A physical object transmits energy through physical contact, as when one billiard ball transmits motion to another. One human influences another through communication, including the various forms of language expression, genetic transmission, mores, expectations, and fads. Such interactions are transient and are often effected at some distance. The second and more important difference is related to the first. Social systems are purposive—interaction is driven by the cognitive process of decision-making and by motives, interests and sentiments.

MacIver (1964) elaborates on the nature of social interaction in his discussion of two major elements of the "causal nexus." The first element is the social-psychological, or "teleological nexus ... a mode of determination that is peculiar to beings endowed with consciousness, beings who are to some degree aware of what they are doing and who are in a sense purposive in doing it." (MacIver, 1964, pp. 14-15) The second is social—the result of "a great many individual or group actions directed to quite other means but together conspiring to bring them about....We include here ... the standards, customs and cultural patterns that men everywhere follow....These [larger] patterns emerge ... from the conjuncture of diverse activities directed to less comprehensive and more immediate means." (pp. 20-21)

MacIver points to two seemingly inconsistent but complementary sides of the social system. On the one side, humans are directed by individual goals—a somewhat atomistic view of society. On the other side, humans conspire to cooperate, to act as one. The first is teleological; that is, it is concerned with final causation. Final causation projects forward into time; current behavior is motivated (consciously or otherwise) by desired future outcome. Darwin's theory is teleological. The second is concerned with efficient, or physical, causation. Behavior is dependent upon events that have preceded and is consequently unintended. Social systems, according to MacIver, are a product of the dynamic interaction of these forces.

Descriptive researchers have tended to focus on teleological causation or human purposiveness rather than on the dynamic interaction of teleology and efficient causation. The teleological focus fails to explain certain systemic patterns of development. Scientists are beginning to ask broad questions such as, "Why do all leaves have basically the same shape?" The answers are not to be found in final causation; rather, they are to be found with such efficient causal agencies as gravity and its universal effect on systemic development (a magnificently literary argument of this point can be found in Thompson, 1959). The same can be said of social research. There is an unavoidable sameness and constancy about social structures that teleology fail to explain. Tribal behavior in New Guiana is reflected in many ways by community life in the United States. Family life is an amazingly stable phenomenon. MacIver argues that it is efficient causation, such things as mores,

customs and even the physical structure of the human body, which generates this universality of form in human behavior. Teleology alone is insufficient to describe social dynamics. Teleology explains diversity but efficient causation describes commonality. Social systems are the product of both forces.

It is such interaction that creates a chaotic system. Chaos is a science of the evolving, dynamic behavior of whole systems. It presumes teleological pressure that is restrained by dissipative forces (broadly—rather than slavishly—to be represented as efficient causation), the product of which is bounded variety.

A further point about purposive behavior is pertinent. Some have suggested that purposive behavior manifests as nothing more than decisions based "on a variety of inconsistent and ill-defined preferences." According to this model (known as the "garbage-can" model of administration), human decisions are made "on the basis of a simple set of trial-and-error procedures, the residue of learning from the accidents of past experiences, imitations, and the inventions born of necessity." (Cohen, March and Olsen, 1972, p.3) Chaos theory corroborates this position, advocating that causation is the result of seemingly whimsical evolutions of interaction patterns. The garbage can theory, like chaos theory, suggests that decisions evolve out of the happenstance collaborations that occur at a particular juncture in time. There appears to be, then, a certain randomness or non-linearity about purposiveness that compromises its effect on the future. Interestingly, nonlinearity is a key component of chaos theory.

The ultimate question, however, is not whether human purposiveness influences social structure but whether purposiveness deterministically controls it. If one answers affirmatively to the latter question, then the modeling ability of chaos theory is compromised. If we can predetermine how events will evolve, if we can establish linear causal relationships between our behaviors and their outcomes no matter how complicated the causal network, then social chaos does not exist. Realism, however, must dictate the contrary view. Purposive causation is not linear in its impact; it is marked by loosely coupled interactions (Glassman, 1973), causal imbalances (as when a given stimulus has no effect until it reaches a certain critical level; Buckley, 1967, p. 67), the anarchy of coincidence, sensitive dependence on initial conditions, and mutual interaction of component parts. Purposiveness influences but it does not control, and that influence is subjugated to shifting interaction patterns. Without restraint, purposiveness would lead to random, unbounded behavior. With restraint—and we return again to MacIver's argument—social systems exhibit bounded diversity. In other words, social dynamics are chaotic.

Mathematical Model of Chaos

The remainder of this paper will first develop a mathematical model of chaos, and will then demonstrate how that model can be applied to social systems. The mathematical model that will be explored was developed to its potential by May (1976) and used to model biological population fluctuations. The equation is a deterministic, logistic equation that demonstrates some amazingly complex behaviors. It makes the simple assumptions that populations are seasonal and generations do not overlap. This latter, of course, does not describe many events in social systems whose interactions tend to be overlapping and continuous; even so, the equation will serve nicely to demonstrate key principles (others have also used logistic equations to model social events; see, for example, Forrester, 1969 and 1971; for discussion of Forrester's methodology, see Bloomfield, 1986).

The formula represents a feedback or recursive system and is written in the form $x_{n+1}=kx_n(1-x_n)$. It sets a given biological entity's population (say the population of Gypsy Moths) to a fractional variable x. The equation predicts population growth within a subsequent cycle (x_{n+1}) based on the size of the immediately preceding population (x_n); that is, the result of each calculation is fed back into the equation for subsequent calculation. The parameter k represents any of a number of biological constraints, such as birth rate.

The formula is more intuitive when written in the form, $x_{n+1} = kx_n - kx_n^2$. The first of the two terms in this form of the equation, kx_n, is a first order term which represents birth rates within the population of interest. The second of the two terms is a nonlinear, quadratic term. When x is small, its effect is negligible; for example, when x is .01, x^2 is .0001. As x increases, however, the quadratic term, being negative, places increasingly greater restraints on the first term. This second term represents the population death rate. If x is sufficiently small, the given population will rise steadily for k greater than 1 and will drop steadily for k less than 1. If x is large, then population growth is dominated by the second term, or the death rate.

With a given value of k and a starting point x_0, the evolution of the population is fully determined. Were x_0 to be .03 and k to be 1.5, population evolution could be represented by Figure 1. Note that a steady state, or balance between birth and death rates, is achieved at a population size of .3333.

Insert Figure 1 about here

For any $k < 3.0$, such steady state will be achieved; however, at $k = 3.0$ a new mathematical phenomena is observed. Population size no longer achieves a steady state; rather it becomes unstable. At $k = 3.2$, steady state is again achieved, but it fluctuates between two values, .799 and .514, as shown in Figure 2. This is known as a period-2 cycle. As k further increases, the population again destabilizes, then at $k = 3.5$, it achieves a period-4 steady state. Further increases in k take the population through subsequent period doublings, each of shorter duration than the previous one. At $k = 3.57$, there are an infinite number of periods and fixed points, and the system has reached a chaotic state.

Insert Figure 2 about here

Period doubling is better illustrated by plotting given values of k against their corresponding points of stability in what is called a bifurcation diagram. Such a diagram is illustrated in Figure 3. Note that bifurcations occur at $k = 3.2$ and again at $k = 3.5$, as described in the previous paragraph. Were this to be continued for additional values of k, the cascade of period doubling would continue, and the bifurcation diagram would look like that represented in Figure 4. Careful examination of this figure reveals the initial bifurcations and the rapid cascade into chaos. An interesting phenomenon is indicated by the clear, vertical bands. At these points, brief periods of stability emerge which quickly evolve again into chaos. At $k = 4.0$, the system dies; the population destroys itself completely by overburdening the supporting environment.

Insert Figure 3 about here

Insert Figure 4 about here

Application in Social Sciences

Figure 4 models not only the growth of biological populations but social interactions as well. Illustration of this assertion refers to classical information theory. Information theory postulates that social structures are organized by constraining communication linkages among humans in much the same way that bridges are fashioned from orderly linkages among steel beams. Specifically, an organized state is created when communication linkages are constrained. The corollary of this is that disorganized states exist when communication linkages are unrestrained. A manufacturing concern organizes by channeling lines of communication—opening some lines and closing others. Families are structured around, among other things, the constraint of sexual interaction. However, constraint reduces the amount of information that a social system can generate, and excessive constraint—an organization with a limited number of linkages—is predictable and dull. This can be problematic. Unless the organization possesses at least as much information (more accurately, variety, or freedom to select among alternatives) as is found in its environment, it will be unable to adequately process environmental demands (Buckley, 1967, p. 89).

Organization, then, can be illustrated as a continuum stretching between a perfectly disorganized state (absolute entropy) and a perfectly organized state (absolute negative entropy). Open systems lie somewhere in the middle of this continuum; they deliberately introduce variety to maintain a dynamic state.

For illustrative purposes, attention is focused on situations in which something of a relationship exists between degree of organization and energic input. Energic input is defined as effort expended to achieve a given organized state. Such effort is usually transmitted as information, but its function is to decrease, rather than increase, variety. For example, a supervisor must expend effort to reduce non-productivity among workers or to reduce the effect of informal group collaboration on organizational function. There are, of course, circumstances in which organization is a natural state of affairs and little energic input is required; indeed energic input is required to avoid variety reduction. For instance, isolated tribes of Indians in the Baja must expend significant energy to find wives (introduce genetic variety) because of strict taboos against even the remotest forms of incest (Owens, 1965). The conclusions proffered by this paper arguably apply to this latter type of phenomenon, but I have chosen not to focus on it.

If, in the logistic formula developed above, we let k equal the energic input required to create organization and x equal the degree of organization, a chaotic model of social systems can be derived. As with the evolution of population growth, certain levels of energic input generate an organization that evolves predictably to a steady state while increased energy leads to bifurcation and destabilization. For example, close supervision of line workers generates initially a greater degree of attention to operational detail. Once the level of supervision passes a certain point, however, alternate behaviors manifest, such as resistance. Alternate states, like resistance and compliance, coexist, and social factions can easily slip from one state to another. Were supervisory pressure increased even further, each of the alternate states would again bifurcate. Resistance, for example, may evolve into organized and passive activity. Eventually, were the pressure to continue its increase, a seemingly infinite, unpredictable variety of states would be possible, and the process could eventually lead to the alteration of the system.

Several concepts need explication the first of which is the concept of steady state. Steady state in social systems and in chaotic physical systems is somewhat different from steady state in the classical sense. Mechanical equilibrium is not implied; sociologists have expended a great deal of energy over the past 50 years or so dispelling that notion (see, for example, Buckley, 1967) and I certainly agree. Systems in equilibrium are linear and predictable; Galileo's pendulum is an appropriate metaphor. Social steady states, like chaotic steady states in physics, are non-periodic but finite in scope. If certain behaviors of a social system were quantifiably monitored over time and plotted on a graph (e.g., a three dimensional plot of average intensity of worker attitudes about supervision, predominant nature of worker behavior, and level of supervision), the resultant lines would not settle into a repetitive pattern as they would if one plotted a pendulum's velocity against its position.

Rather the plotted lines would swirl and loop on the graph. More importantly, however, the lines will remain within a finite area (the area of the graph) rather than fly off into infinity. Organizational behavior represented by these lines is finite, constrained by forces such as role expectations, mores, and human capability. Steady state, then, refers to the finite nature of human activity. It is relatively constant over time and situation and allows generally predictable organizational behavior free of significant disruption.

Steady states are also non-periodic. Referring again to the three dimensional graph of organizational behavior described in the previous paragraph, no two lines or swirls will overlap, and magnification of any given line will reveal that it is composed of successively smaller lines. By extension, human behavior never quite repeats itself. Behavior that appears repetitive is, upon close examination, different in some subtle way from anything that precedes. Social behavior may at times appear cyclical, but that is never quite the case. Human behavior, both individualistic and social, is infinitely varied.

The force that binds the system (i.e., creates the steady state) is the strange attractor. It is an attractor because it limits behavior just as gravity limits the behavior of a pendulum; it is strange because the behavior, though constrained, is non-periodic. An attractor is a metaphorical basin or magnet which attracts behavior. The analogy can easily be extended to MacIver's concept of social nexus. MacIver's purposive behavior is, in the terminology of chaos, non-periodic, while his social nexus is referred to in chaos as strange attractor. Perhaps the closest analogy in current organizational theory is the notion of "culture," defined as "a pattern of basic assumptions ... that has worked well enough to be considered valid and, therefore, to be taught to new members as the correct way to perceive, think, and feel in relation to ... problems." (Schein, 1985, p. 9)

The concept of scaling is required to put these concepts into perspective. Scaling is not evident in May's bifurcation diagram, but in other types of representations, particularly those of Mandelbrot, (1983) it is well illustrated. Any given phenomenon is reproduced imperfectly and in miniature by a number of sub-phenomena, and each of these sub-phenomenon is again replicated in miniature, and so on ad infinatum (at least mathematically). Thus organizational steady state is composed of a number of smaller steady states and each of these is composed of even smaller steady states. To represent steady state as a series of points ($k < 3.0$) is technically inaccurate. The steady states represented by those seemingly static points are actually small eddies of chaos. Graphically, they look like the turbulent region right of $k = 3.0$ on a much smaller scale. They a` are bound by the same strange attractor, and each is composed of smaller chaotic states. They are quite dynamic, with movement both within the chaotic state and along the line of the graph.

With bifurcation, steady states begin to destabilize—behavior within the group fluctuates more vigorously. As pressure increases, so does social turbulence. The chaos of steady state is manifested on a grander scale. It is chaos of such magnitude that one or more alternate steady state may evolve. If steady state is represented as a basin, an orbit that attracts behavior, then the state of social chaos modeled to the right of $k = 3.0$ represents behavior that has moved to the periphery of the basin and which may very well jump to another basin (strange attractor). A classic analysis by George Brager of sociologist Lewis Coser's (1956) assertions about group behavior is illustrative. Coser proposed that conflict inflicted by external sources tends to coalesce the group under attack. Brager (1969) studied the behavior of employees in a social agency which was under public attack because of the agency's alleged extremist views. He found, contrary to Coser, that the external pressure caused dissention within the ranks of the agency. His hypotheses dealt specifically with level of commitment to ideal and level of dissention (his findings were generally supportive), but along the way he spoke of bifurcation (dual reaction of administration and dual reaction of individuals) and of changing sentiments (administration's first response to the crisis was to defend its values; it subsequently shifted to a defensive position of compromise). Such clues indicate that a chaotic model of organizational dynamics over time would have offered a different, if not more interesting, perspective of what tran-

spired in this social agency. Chaotic modeling would certainly have supported Brager and contradicted Coser.

It is incorrect to assume across the board that degree of organization increases linearly in relationship to degree of energic input. While the organization is experiencing steady states, the assertion is more or less true. However, once bifurcation begins, the cascade of period doubling (i.e., the appearance of alternate, transient states) transpires at an increasingly furious rate. Michael Feigenbaum (1978) found that a period-2 cycle is 4.6692016... times longer than a period 4 cycle; a period-4 cycle bears the same relationship to a period-8 cycle, and so forth. The point here is not in the mathematical rigor but in the fact that period doubling, once it begins, occurs at progressively smaller intervals of time or energic input. In the example regarding supervision, it would seem that employes become increasingly sensitive to supervision once a critical level is exceeded and react with increasing rapidity to elevations in the level of energic input.

Information theory suggests that "randomness," or the ability to select among choices, is necessary for system survival. An organization must possess at least as much information as it must deal with from its environment (Buckley, 1976, p. 88-89). Information issues from unconstrained linkages within the organization. Using the metaphor explored by this paper, information evolves out of chaos, a process which, contrary to information theory, is not random. Verification of the necessity proposal has come from several chaoticians. Medical researchers, for example, have concluded that chaos is integral to human survival. Ary Goldberg has found that some degree of chaos contributes to the healthy functioning of the heart by allowing it to adjust to environmental contingencies, and that a regular heartbeat may signal impending problems (see Taubes, 1989). Gleich (1987, pp. 193-4)) summarizes:

> Nonlinear feedback regulates motion, making it more robust. In a linear system, a perturbation has a constant effect. In the presence of nonlinearity, a perturbation can feed on itself until it dies away and the system returns automatically to a stable state....biological systems use their nonlinearity as a defense against noise.

It is a simple step from this to the conclusion that chaos is necessary for the survival of the social system—the analogies are obvious.

Earlier in this discussion bands of stability (indicated by white horizontal strips in Figure 4) were noted within the chaotic region. It is difficult to document this as a mathematical phenomenon related solely to the given level of energic input. The difficult comes not in imagining that such bands of stability would evolve—they may, for example, represent temporary cease-fires, brief breathers, temporary alliances, or futile efforts to "get it back together." What is difficult to imagine is a blind linkage to mathematics rather than to purposive behavior. It is more appropriate to assert that these bands model a statistical probability rather than a mathematical invariant.

This, however, raises question about the utility of mathematical modeling of social behavior. It is not suggested that these models precisely replicate behavior; rather, they are stylistic representations. This is true not only of social systems, but of models of physical system as well. The problem is environmental noise (such as purposive behavior). Libchaber (1982), who has experimented with turbulent fluids, was concerned about the effect of bumps and vibrations on his experimental apparatus. Noise in social systems is even more pervasive. Noise contributes to unpredictability in chaotic structures; one cannot predict where, when or the degree to which noise will strike. Consequently, although behavior is ultimately bound by the strange attractor, one cannot predict the impact that noise will have on the system. Thus chaotic models are caricatures, but they are proving to be extremely useful caricatures. Scientists are using them to test theories that have failed to yield to linear techniques (Peterson, 1988, p. 148). Benoit Mandelbrot (1983) has used stylized representations to more accurately understand such things as static in telephone transmission and stock market evolution. Chaotic modeling will not bring precision to measures of social dynamics. However, it can measure—albeit stylistically—aspects of

social systems that have been previously unmeasured thus significantly improving our understanding of human dynamics.

Figure 5 provides an alternate representation of the continuum from disorganized to organized states typically proposed by information theory. The notion of continuum is abandoned in this representation, for once the restrictions on flow of information reaches a critical point and the chaotic region is entered, a variety of organizational states are manifested. Figure 5, instead, allows for a range of behaviors across various energic levels. If information linkages could indeed be restrained to the degree suggested by informational theory's straight line continuum, then linear growth to absolute organization could be predicted. This thesis argues that they cannot be so structured.

Insert Figure 5 about here

Information theory concludes that increased structuring of systematic communication linkages reduces its generated information to the point that it becomes non-viable. Chaos theory indicates instead that pressure to reduce communication dramatically increases the amount of information produced by the system; that is, it increases the amount of chaos. Nonetheless, non-viability threatens both the system envisioned by information theory and that envisioned by chaos. The difference, however, is that one envisions a quiet death while the latter projects alteration related to turbulent activity.

Summarization

The introduction to this paper referred to debates among organizational theorists about positivism, voluntarism, and structuralism. One camp in these debates argues, to one degree or another, the stability or structural nature of organizations, while the other argues the transient, purposive nature of organization. At the turn of this century, for example, process models of society—the major product of the Chicago School—emphasized the transient, fluid nature of stability. Small (1905, pp. 619-620), an advocate of this model, asserted that "... social structures and functions are ... results of ... previous associational process; but they no sooner pass out of the fluid state, into a relatively stable condition, than they become in turn causes of subsequent stages of the associational process ...". By the middle of this century, the functionalist model championed by Parsons advocated the interaction of stability and pressure to change (Parsons and Smelser, 1956), with the emphasis on stability. More recently, systems theory has proposed a homeostatic model in which the interaction of maintenance and adaptive structures cause constant but non-disruptive adaptation (see, for example, Hoy and Miskel, 1987).

Chaos theory adds yet another perspective to our understanding of the relationship between purposiveness and stability. Specifically, it addresses the nature of organization, the nature of change, and the nature of social cause-effect.

Several observations about the nature of organization can be derived from the study of chaos. First the concept of equilibrium is rejected in favor of steady state, defined as non-periodic but finite behavior. Steady state suggests an interactive relationship between purposive, teleological behavior and social stability. Purposiveness serves to define the non-repetitive, dynamic nature of organization, to compromise the stodginess of stability. Stability (or strange attractor), on the other hand, serves to restrain the effect of purposiveness, to insure that behavior remains within certain bounds.

Second, organization must be understood in reference to scaling. Scaling suggests that a given organization is a chaotic entity composed of lesser chaotic entities, each of which are in turn composed of chaotic entities within chaotic entities. Each lesser entity is a rough replication, on pertinent organizational dimensions (technology, values, culture, structure, etc.), of the chaotic states from which it is derived. This is true because lesser systems are

bound not only by their own internal strange attractors, but, as part of a larger chaotic state, are also constrained and shaped by the larger attractor.

Third, chaos is crucial to the survival of the organization. Because chaotic systems function nonlinearly, a chaotic structure can absorb perturbation or invasion and neutralize its impact on the system. Were system dynamics linear, perturbation would have an effect similar to the chain reaction obtained by placing 1000 ping-pong balls on the spring arms of 1000 mouse traps and launching a loose ball into the mix. The slightest bump against a linear, interactive system can be devastating. Nonlinear systems, on the other hand, use feedback to turn a perturbation in on itself until the perturbation dies away. Chaos gives a system the flexibility it needs to deal with a contingent environment. For example, schools tend to absorb and neutralize the infusion of new ideas and personnel, and return quickly to the steady state that existed prior to the intrusion. Organizational informal groups tend to neutralize change sought by administrators.

The issue of change is an important one in chaos. It was just argued that chaos provides a system the ability to resist perturbation or change, a fact which increases its survivability. A system that fails to change, however, is unviable. Chaos balances the seeming incongruity of change and stability. It prevents devastating, linear change, yet is itself the image of change. Paradoxically it uses change to control change. The image of a stick (perturbation) thrown into a swirling stream is appropriate. The stick, rather than "parting the waters," becomes caught up in the stream's chaotic agenda.

I do not, by this, suggest a non-evolving strange attractor. While the seeming incongruity of stability-promoting change may strain the imagination, the incongruity of an unchanging stability strains credulity. A social system modifies its strange attractor over time; periodically it also jumps from one strange attractor to another. The first of these assertions has not been developed in this paper, but it would be absurd to deny. The strange attractor, while exerting a significant influence over purposive behavior, must itself be influenced by purposiveness. Stability evolves to deal with contingency, to bring order to purposiveness; thus as purposiveness pushes social structures into unique situations, stability must further evolve to deal with the new conditions.

Attractor adjustment, however, does little more than elaborate the existing structure. Attractor shifts, on the other hand, are truly structure changing. This phenomena was suggested by the mathematical model developed within the body of this paper. A shift across attractors was recently observed on a rather dramatic scale in eastern Europe. One also observed shifts between strange attractors in the turmoil of the sixties and in the conservative movement of the eighties. In education, shifts have been observed with the excellence movement of the eighties, the Sputnik crisis of the late fifties, and the concern about the underprivileged in the sixties. Kuhn (1970) observed attractor shifts when he described precipitous historical evolutions in scientific knowledge, as occurred when Newton advanced his theories of gravity and motion, and Einstein advanced his theory of relativity. Such shifts mark rather precipitous changes in a system's basic direction.

The final major derivative of this paper deals with cause-effect. It has been asserted that non-linear, chaotic structures absorb cause or perturbation, constraining its effect within bounds established by the strange attractor. This is not to say that effect is predictable. A perturbation can cause any of an infinite variety of behaviors within the confines imposed by the strange attractor. Further the intensity of cause and of effect need not be linearly related; as Lorenz noted, the flapping of a butterfly's wings in Tokyo may conceivably cause thunderstorms over Texas.

The chaotic view of cause-effect naturally questions the efficacy of traditional statistical analysis which seeks probabalistic relationships and causalities among variable. Chaos offers something of a different perspective of causality, a perspective of systemic wholes and of change over time, thus care should be exercised in comparing the two analytical approaches. It should be noted that the formulas used to model chaos, like those used by statistical research, are deterministic. It is the nonlinear component of chaos rather than determinism that is at variance with traditional research, thus it is not incongruous to find de-

terministic relationships when one focuses on a temporally static view of phenomena. Further, attention is drawn to the darker bands in the chaotic regions of Figure 4. These bands indicate that certain behaviors are visited more frequently than others, a fact which may contribute to the observations of traditional research.

A final observation about causality refers again to attractor shifts or precipitous change in social structure. Such events may be caused by increased energic input or through happenstance events. The effect of energic input from internal sources was modeled by the formula developed by this paper. Energic force can likewise be exerted by the interaction of two or more systems, as has occurred with the interaction of technology and social life (television, for example, has undoubtable been a major influence on what is known as the sexual revolution). Attractor shifts may also occur more casually, the incidental result of a trajectory embarked upon. Thus, as the poem says, the loss of a nail in the horse's hoof led to the loss of the kingdom. It is difficult to say whether the racial equality movement of the 1960s received major impetus from the dynamism of John Kennedy or evolved out of a rather innocuous Supreme Court case in the 1930s which forbade Missouri from refusing to let a black attend the University of Missouri Law School (Missouri ex rel. Gaines v. Canada, 1938); the latter, however, may very well have been more influential than generally credited.

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Figure 1. Evolution to a steady state when x = .03 and k = 1.5.

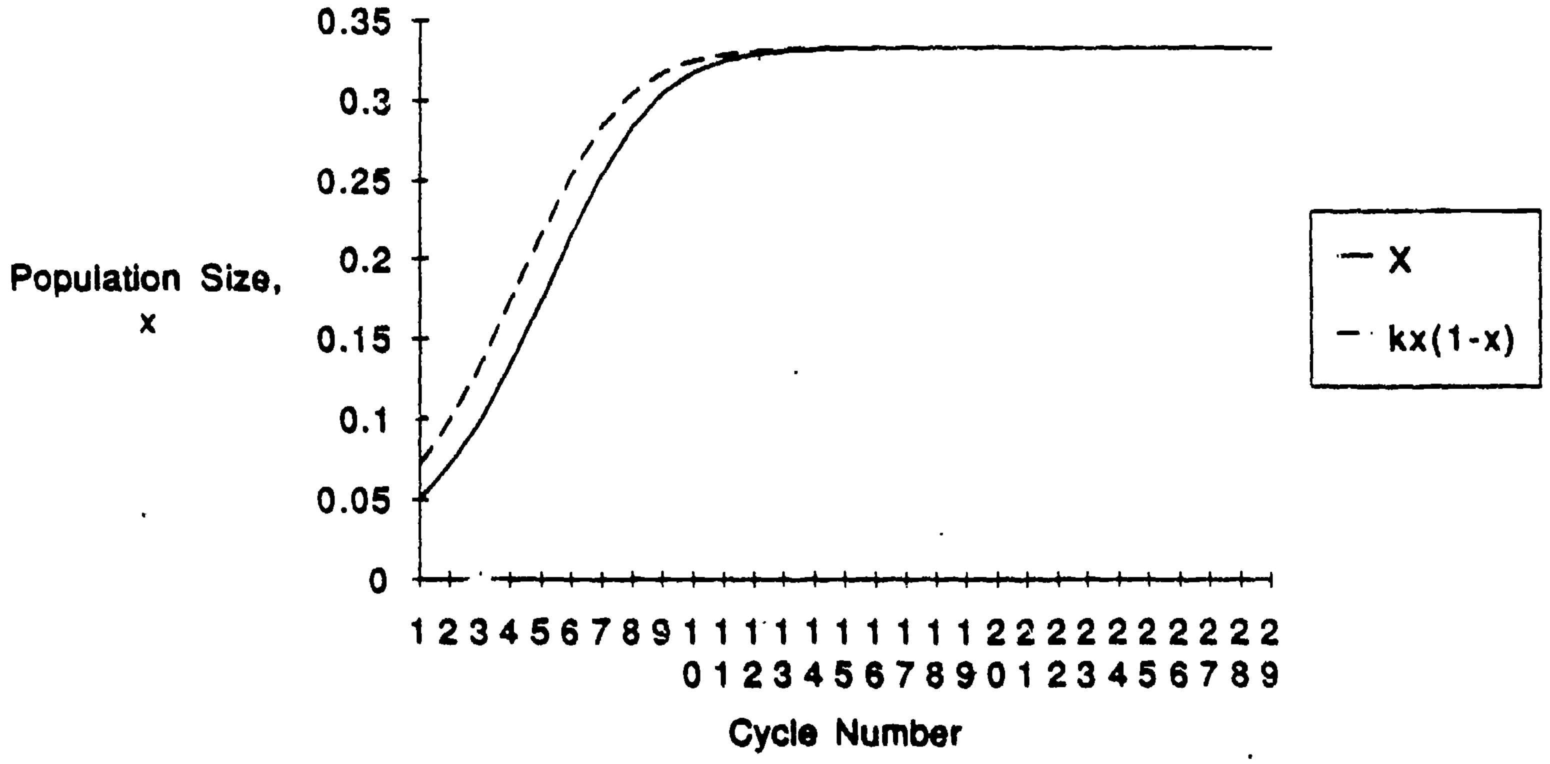
0.35
0.3
0.25
0.2
0.15
0.1
0.05
0
Population Size, x
Cycle Number
x
kx(1-x)

Figure 2. Period-2 steady state when x = .03 and k = 3.2.

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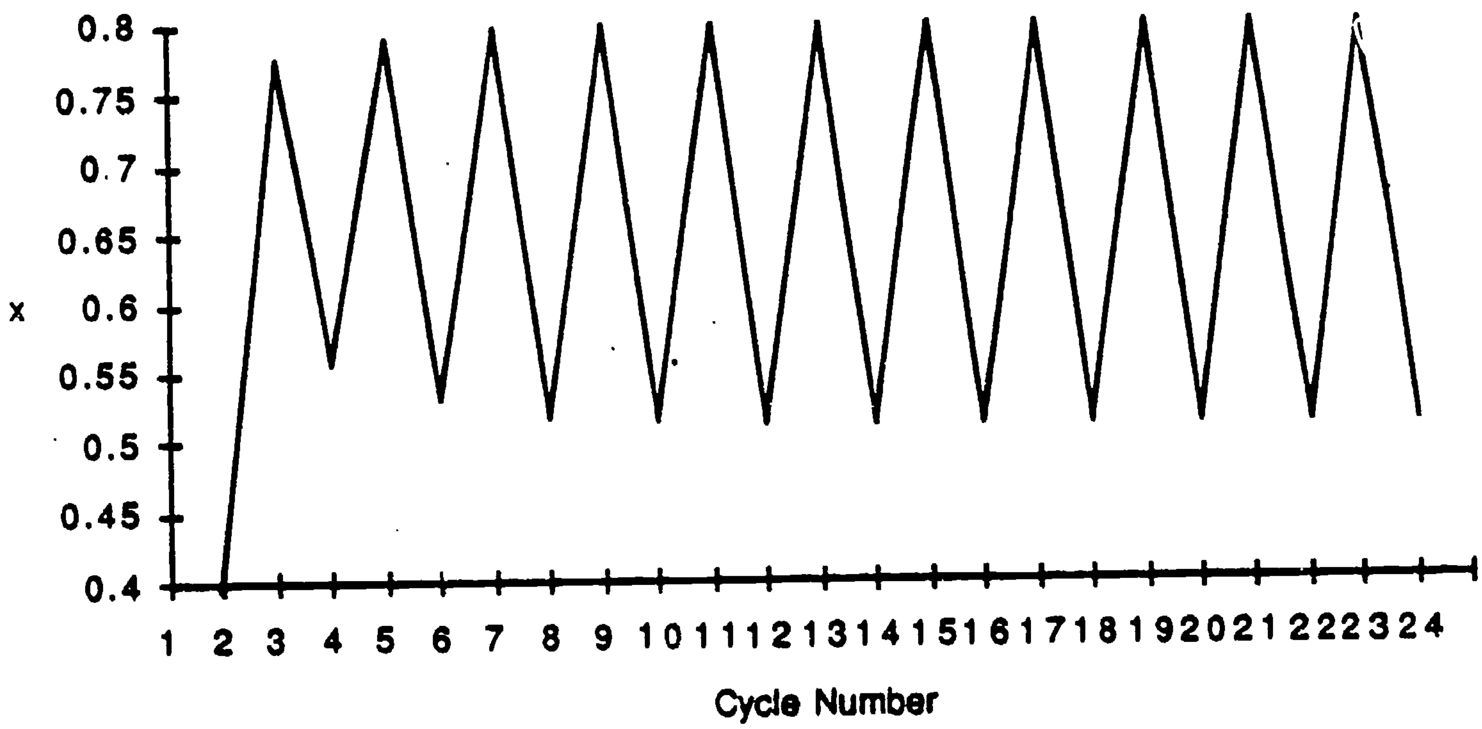
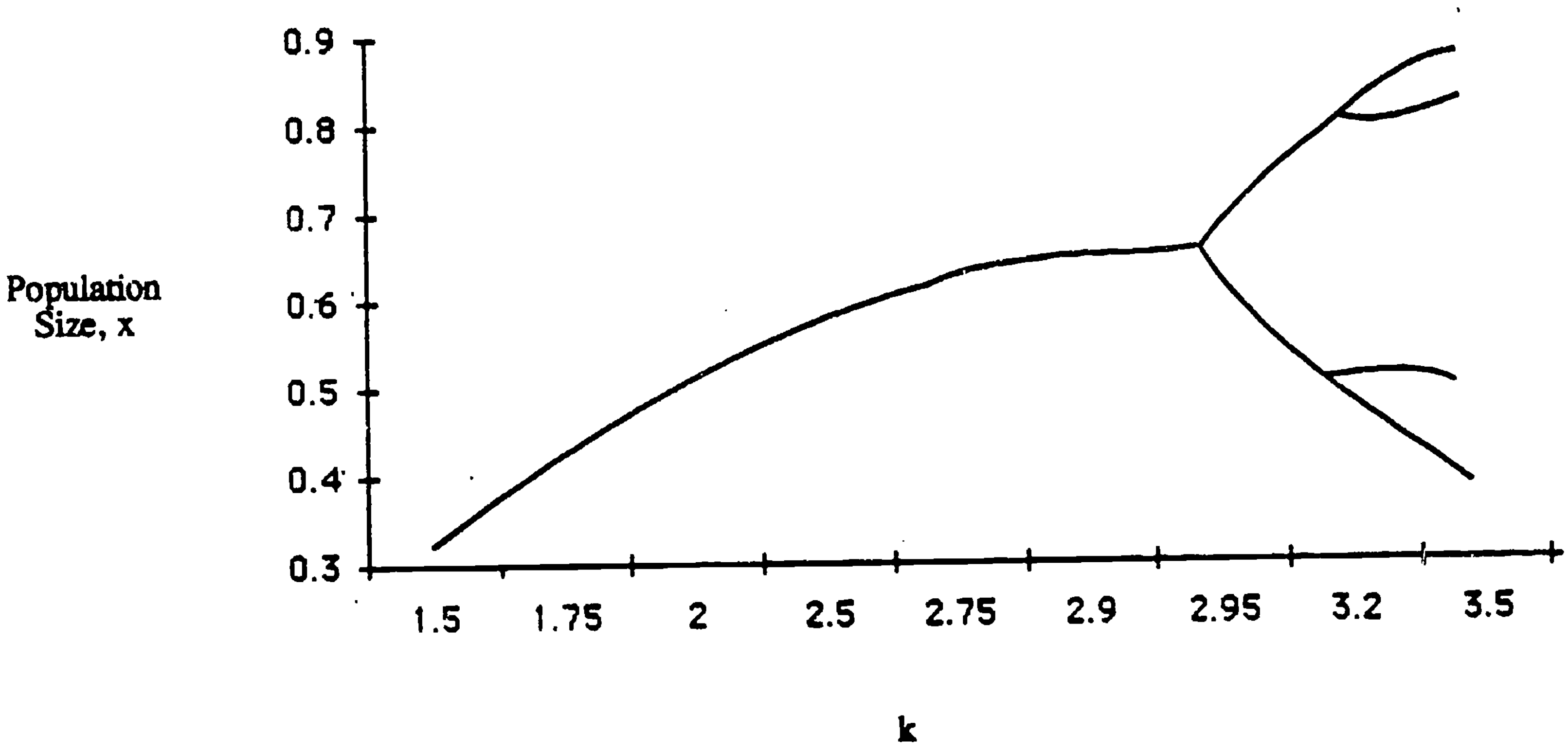

0.8
0.75
0.7
0.65
x
0.6
0.55
0.5
0.45
0.4
1 2 3 4 5 6 7 8 9 101112131415161718192021222324
Cycle Number

Figure 3. Bifurcation of population size (x) in biological systems across increasing values of k.


0.9
0.8
0.7
0.6
0.5
0.4
0.3
Population Size, x
1.5
1.75
2
2.5
2.75
2.9
2.95
3.2
3.5
k

21

Figure 4. Bifurcation and chaotic range between k = 3.5 and k = 4.0. Note: From Turbulent Mirrors (p. 61) by John Briggs and F. David Peat, 1989, New York: Harper & Row. Copyright 1989 by John Briggs and F. David Peat. Adopted by permission.

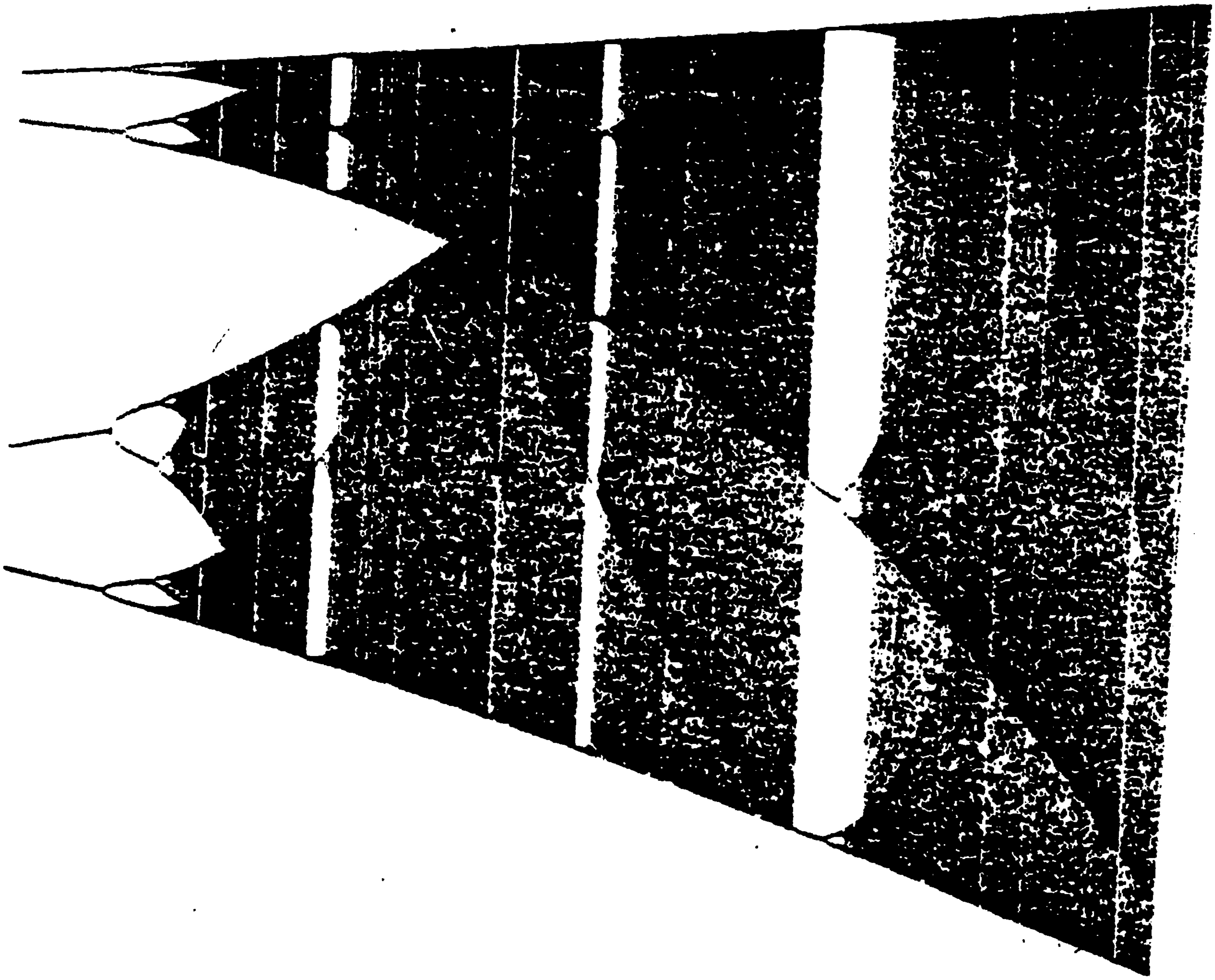
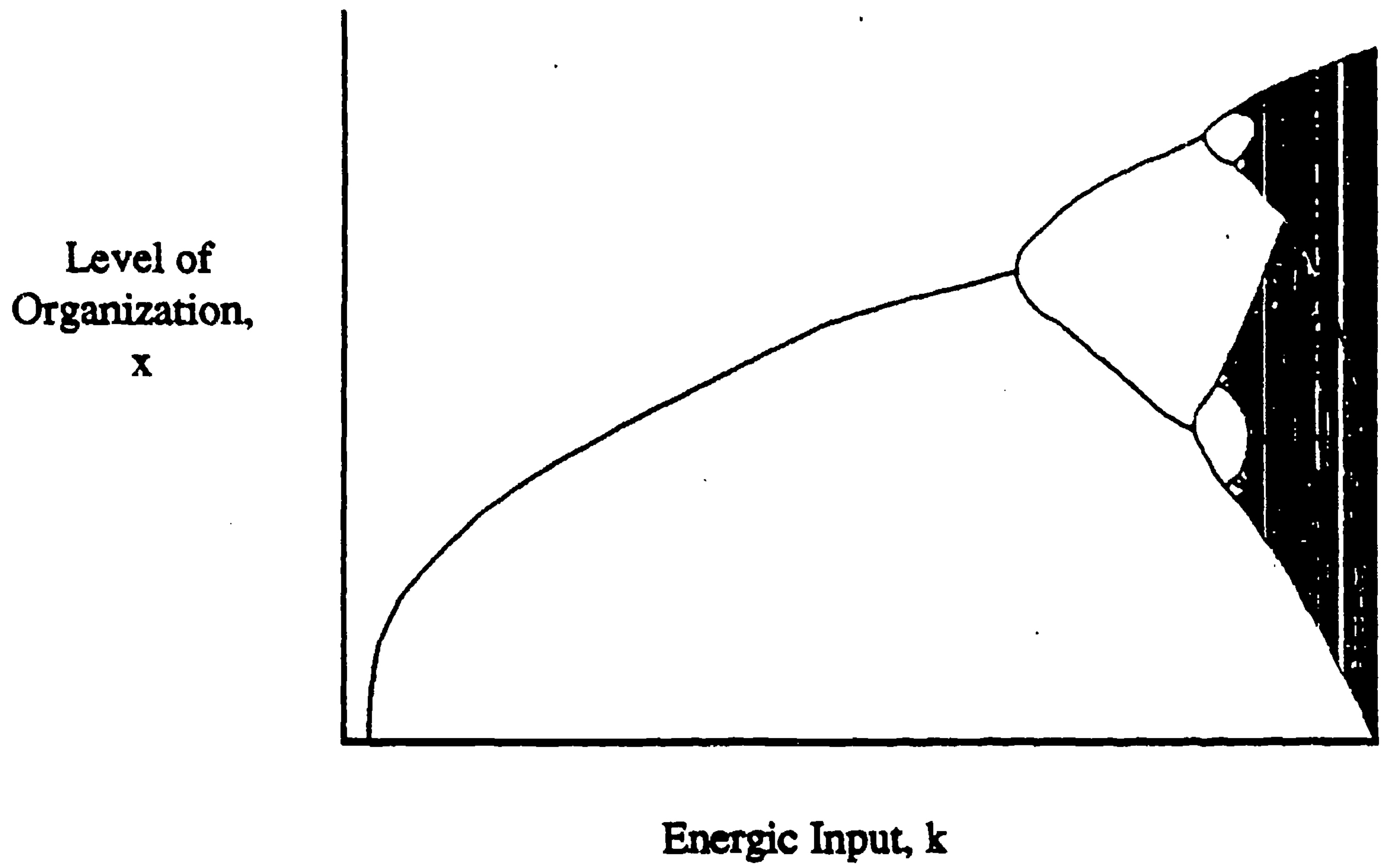


Figure 5. Model of the chaotic evolution of organized social systems.



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